Gadopsidæ. In the Cat. Col. Mus. 1870, I recorded the occurrence of *Gadopsis marmoratus* in New Zealand ; but it has dropped out of subsequent lists, being only represented in the collection by a drawing made of a specimen got on the east coast.

XXXIV.—*Observations on the* Coccosphere. By G. C. Wallich, M.D., Surgeon-Major Retired List H.M. Indian Army.

[Plate XVII.]

The history of what may be termed the Coccosphere question is a remarkable one. Seventeen years ago I pointed out, as the result of actual observation, that the "coccoliths," which had been discovered three years previously by Professor Huxley in soundings from the Atlantic, are not independent structures, but merely cast-off appendages of the Coccosphere-cell. Yet, from that period to the present, the physiological relation existing between these two integral portions of one and the same organism has remained shrouded in mystery. Since 1868 a number of elaborate observations have been published, both here and abroad, on the characters and supposed affinities of the various forms of "coccolith." But, unfortunately, the value of these observations has been materially diminished, owing to their being based on one or other of the following essentially fallacious assumptions :—namely, that the "*coccolith*" itself is a "cell;" that it is an independently developed and independently living structure; and that, as a "*coccolith*," it is capable of taking part in any subsequent vital combination.

These assumptions have possibly had their origin in two statements made by Prof. Huxley :—the first, in 1858*, that "*coccoliths* somewhat resemble single *cells* of the plant *Protococcus*;" the second, ten years later, namely in 1868†, that the varieties of "*coccoliths*" named by him "*Discoliths* and *Cyatholiths* stand in the same relation to the protoplasm of *Bathybius* as the *spicula* of sponges or of *Radiolaria* do to the soft parts of these animals." It is true that in the same paper Prof. Huxley noticed three alternative "possibilities" in relation to the *cocco-*

* 'Deep-sea Soundings in the North Atlantic,' made in H.M.S. 'Cyclops,' Commander Dayman, in 1875. Appendix, Report on Soundings, by Prof. Huxley, p. 64.

† "On some Organisms living at Great Depths in the North Atlantic Ocean," by Prof. Huxley, F.R.S., 'Quart. Journ. Microsc. Science,' Oct. 1868, p. 210.

spheres. But any one who carefully studies his remarks must, I think, conclude that, on the whole, he was disposed to give "*Bathybius*" the benefit of the doubt, and to regard the *coccospheres* as subsidiary productions due to "the coalescence" of the "*coccoliths*"—a view, which then, as now, I venture most respectfully to contest. For although the supreme interest that centred in the "*coccoliths*" has waned since they ceased to constitute the bones of *Bathybius*, we must not forget the important part already played by them in the construction of certain rocks, and which they still continue to play in the construction of certain oceanic deposits. I may be pardoned therefore for seeking to redeem the coccosphere-question from the chaos into which it has drifted, and for suggesting that had the fact indicated by me in a paper "On the *Polycystina*" (read at the Royal Microscopical Society in 1865), namely that I "had met with *coccospheres* as free floating organisms in tropical seas" in 1857, been recognized as I think it ought, Sir Wyville Thomson would have abstained, in 1872 *, from casting unmerited doubts on my view regarding the true relation of the "*coccoliths*" to the *coccospheres*, and, in 1874, from adopting and publishing that view as a new and original observation made on board the 'Challenger' †.

From first to last in my published writings on the subject, I have never made the statement so persistently attributed to me (and which involves a contradiction of the opinion really entertained and expressed by me), namely that "sometimes the coccoliths are found aggregated into spheroids" (see 'Lay Sermons,' "On a Piece of Chalk," by Prof. Huxley, 5th edit. 1874, p. 186) ‡, but have invariably adhered to the opinions

* "Sometimes the '*Coccoliths*' are found aggregated on the surface of small transparent balls, and these, *which seemed at first to have something to do* with the production of the 'coccoliths,' Dr. Wallich has called '*coccospheres*.'" (Sir Wyville Thomson, 'The Depths of the Sea,' 1872, p. 413.)

† "I need only say that I believe *our* observations have placed it beyond a doubt that the 'coccoliths' are the separated elements of a peculiar calcareous armature which covers certain spherical bodies (the 'coccospheres' of Dr. Wallich)." (Sir W. Thomson, 'Proceedings Roy. Soc.' vol. xxiv. No. 154, Nov. 1874, p. 38.)

‡ See also 'The Microscope,' 5th edit. 1875, p. 464, where Dr. Carpenter speaks of "the larger spherical *aggregations* first observed by Dr. Wallich, and designated by him as *coccospheres*;" and at p. 466, "The coccospheres are made up *by the aggregation of bodies* resembling cyatholiths." As (in the 'Introduction to the Study of the Foraminifera,' 1862, pp. 46–7) Dr. Carpenter quoted almost *in extenso* both the description and figures of "*coccoliths*" and *coccospheres* given by me in 'The Annals' of July 1861, it is difficult to see how he could so completely have misunderstood what I both described and figured.

of which a correct *résumé* is given in my paper "On Deep-sea Protozoa" ('Monthly Micr. Journ.' Jan. 1869)—namely, that after a careful and long-continued study of these organisms, whether occurring as free floating inhabitants of the surface-waters of the Indian Ocean and mid-Atlantic, as components of the present deep-sea deposits, in a fossil condition in the post-tertiary earths, or as living organisms in the British Channel, I have never deviated from the opinion that the free *coccoliths* are derived from their parent *coccospheres*. In some deep-sea deposits, as stated by Prof. Huxley, free *coccoliths* undoubtedly occur in overwhelming number as compared with the *coccospheres*; but it is equally true that *coccospheres* are, at times, present in great abundance, whereas free *coccoliths* are comparatively scarce. Coupling these facts with the very important one, that perfect *coccospheres* are to be met with of every intermediate size between the $\frac{1}{5000}$ and $\frac{1}{830}$ of an inch in diameter, I am induced to believe that the free *coccoliths* are, *in every instance*, formed on, or *pari passu* with, the spheroidal cells on which they rest, *their state of attachment to these cells being their normal as well as pristine condition*. That they revert at any future stage of their history, after once becoming free, to their original composite state, there is no recorded evidence forthcoming to prove. (In an appended footnote it was stated that "some of the *free-floating coccospheres are oblong*.") Lastly, I stated (*loc. cit.*) (with reference to the "granular zone" which Prof. Huxley described as *possibly* forming a normal portion of the coccolith), that "amongst the immense numbers of coccospheres which had been examined both in the recent state and in the preserved though still recent material of the soundings, I had never met with any proof that this zone exists as an integral portion of the structure; nor had any evidence presented itself" that the "granular zone" is any thing more than an accidental accretion, *or that its presence is due to any inherent condition without which the organism would be incomplete.* ("On Deep-sea Protozoa," 'Monthly Micr. Journ.' Jan. 1869, pp. 35 and 36).

Having thus far shown that there is no reason to suppose that the *Coccosphere* is a secondary formation, resulting in any way from an "*aggregation*" of independently developed "*coccoliths*," but that the balance of evidence is altogether in favour of the view that the "*coccoliths*" are normally developed upon, and simultaneously with, their parent *coccosphere*, I have now to state the grounds on which I base the opinion that the "*coccolith*" presents none of the characters of a true "*cell*."

Although Prof. Huxley, in his first brief notice of the coccoliths (already referred to as having appeared in 1858) described the "*coccolith*" as being somewhat like a single cell of the plant *Protococcus*," he has nowhere asserted that it is a cell. In his paper describing *Bathybius* ('Quart. Journ. Micr. Science,' Oct. 1868, p. 207) he alludes to "*a central corpuscule*," and says, "*there is in its centre a clear and transparent space*," adding that "sometimes, as Dr. Wallich has already observed, the clear space is divided into two. This appears to occur only in the largest of these bodies; but I have never observed any further subdivision of the clear centre, nor any tendency to divide on the part of the body itself." In the same paper Prof. Huxley pointed out, for the first time, the double or *shirt-stud*-like figure of the "*coccoliths*," a feature which I had altogether overlooked, owing, doubtless, to my attention having been chiefly directed towards the *Coccosphere* as a whole.

Now *every thing* depends on a correct interpretation of what Prof. Huxley describes as the *central corpuscule* and the *clear space* at its centre. He says, "Suppose a couple of watch-glasses, one rather smaller than the other; turn the convex side of the former to the concave side of the latter; interpose between the centre of the two a hollow spheroid of wax, and press them together: these will represent the upper and lower plates and the central corpuscule" (loc. cit. p. 207). This description is most closely borne out by Prof. Huxley's figures. To facilitate my explanation, I have reproduced three of his figures in the Plate which accompanies this paper—namely, figs. 13 H, 14 H, and 15 H. It will be seen from these, that if we apply his experimental illustration of the two watch-glasses and the hollow spheroid of wax, where there is *one* clear space in the centre of the central corpuscule, we should have to employ either two hollow spheroids of wax, or one spheroid with two cavities in it, to represent the *coccolith* in which two central clear spaces occur; and so on, whatever the number of central clear spaces may be. To my mind this does not by any means give a correct idea of the appearances; which, on the contrary, indicate that the central clear space or spaces are either single or double perforations in the external disk—its "markings," as it were—and nothing more. They have, therefore, no physiological significance, and certainly do not represent any thing that can be called a cell. See Plate XVII. fig. 10, which gives a diagrammatic sectional view of a coccolith. There is no evidence forthcoming, that I am aware of, to show whether the *stem* of the stud (*i. e.* the intermediate piece between the two disks), is or is not continuous with the disks. As the appearance of concentric rings is constant,

being observable even in the fossil coccoliths, I presume the stem must be continuous with the disks.

Instead of the watch-glasses and hollow spheroid of wax, imagine a shirt-stud made of colourless glass, with a minute shallow hole drilled at the centre of the *larger* of its two disks, which (as in the case of the coccolith) would constitute the outer disk. Imagine this glass stud to be enveloped in transparent varnish or any glairy fluid. On looking down upon it we should see (fig. 5, *b*) a minute central ring formed by the edge of the minute central hollow; external to, and at a little distance from this, a second ring (*c*), formed by the outline of the *stem* of the stud; again, a little external to this, a third ring (*d*), formed by the outline of the smaller of the two disks of the stud (*e*); and lastly, the marginal outline. Of course the multiple "central clear-spaces" might be imitated by drilling a corresponding number of holes in the outer disk (see Plate XVII. fig. 7). Now here we should have precisely the same appearance of concentric rings and central spaces as we find in the "*coccolith*;" and what is more, they would have a similar origin. Of course the only difference observable in looking down on the *coccolith* or the glass stud from the direction of the inner or smaller disk, would be that the "central clear space" would be somewhat less distinct, whereas the outline of the smaller disk would be more distinct.

I have now to refer to Mr. Carter's views as embodied in his paper on "*Melobesia unicellularis*" (Annals and Mag. Nat. Hist., Mar. 1871). Let me, however, at once confess that whilst I dissent, *in toto* (for reasons already assigned), from the view that the "*coccolith*" is, in any sense, "*a cell*," I am quite prepared to adopt Mr. Carter's opinion, if he will permit me, as applicable to the parent and entire structure, namely the *coccosphere* with its "*coccoliths*." The only difficulty I see in the way of regarding the *Coccosphere* as a protophyte, resides in the remarkable evidence of its relationship to certain Foraminifera, furnished by the discovery (at first in one or two specimens only, but afterwards in many) of shells so regularly studded with *coccoliths*, as to suggest the idea that the chambers originated as *coccospheres* *. One thing would seem certain, that this regularity is incompatible with the supposition that the *coccoliths* got into their position accidentally. How then, did they attain it? I once asked Mr. Carter if he could explain the matter; and he obligingly sent

* See my observations on this subject, and accompanying figures in 'The Annals,' for July 1861, p. 55; and in the 'Monthly Microscopical Journal,' for Jan. 1869, pp. 37, 38.

the best explanation I have as yet come across, though even this has a weak point in it. It was, that the animals of the Foraminifera probably employed the *coccoliths*, which abound in the mud, instead of sand or other particles for the strengthening of their shells, as we know to be the habit of a large number of the Foraminifera that live at the bottom of the deep sea. But, although the sparse kind of tessellation with large mineral particles here and there on the shell is undoubtedly characteristic of some species (as for example *Proteonina* and *Buliminia*; and, as I have elsewhere shown to be the case in certain deep-sea Foraminifera as well as freshwater testaceous Rhizopods, "the selective and adaptive power" exhibited in the material and workmanship of the shells is simply marvellous), in the shells now under notice the arrangement of the *coccoliths* appears almost *too* like that observable on the *coccospheres* to render it easily intelligible how the animal of the Foraminifer could have so exactly "mimicked" it. On the other hand, there is a piece of evidence which would seem to support Mr. Carter's view of unicellular algal affinity (supposing it to be extended to the *coccosphere*), namely, an appearance of "dehiscence" which presents itself not unfrequently in the large oblong *coccospheres* met with in tropical seas, and so invariably occurs, at one end only, as to negative the idea of its being accidental (See Plate XVII. fig. 4).

Mr. Carter suggests that the "loose type" of coccosphere described and figured by Prof. Huxley may "be a still more developed form of the *sporangium* or coccosphere, perhaps undergoing dehiscence" (*loc. cit.* p. 189). He will, however, I know, pardon me saying that it is going too far ahead of the evidence to assume that the coccosphere *is* a sporangium at all; for if it be, out of the multitudes I have seen, none has ever departed from the sporangial phase, either in those met with at the top or at the bottom of the ocean. But a glance at the curious object I have depicted (Plate XVII. fig. 18), which I have repeatedly met with in some parts of Bengal, will at once show that Unicellular Algæ do undoubtedly assume a sporangial condition in accordance with that which Mr. Carter must have had in his mind's eye when he suggested that the coccosphere might be a sporangium. My specimen is, I believe, the sporangial condition of a branching stipitate form of *Ankistrodesmus*, each of the kidney-shaped bodies being a frond.

Figures 1 to 4 (see Plate XVII.) represent the only two species of *Coccosphere* I have hitherto met with:—the spherical one being the ubiquitous oceanic form, which I propose to call *Coccosphæra pelagica*; the oblong species, which is not so common by any means, being, so far as my experience goes, confined

to tropical or subtropical seas. I propose to name it after Mr. Carter, *Coccosphæra Carterii*.

The following are the characters of the two species:—

Genus Coccosphæra (Wall.).

1. *Coccosphæra pelagica* (Wall.).

Cell spherical, hyaline, with a distinct membranous wall. Cell-contents, a perfectly colourless glairy protoplasm. *Coccoliths* generally more or less elliptical, numbering from 16 to 36, arranged side by side, and, in the normal state, not overlapping. Central aperture of *Coccolith* single, margin of external disk finely and radially striate. Internal disk plain.

Diameter of *Coccosphere* ranging from $\frac{1}{5000}$ to $\frac{1}{830}$ of an inch. Length of *Coccoliths* from $\frac{1}{9000}$ to $\frac{1}{1000}$ of an inch.

Habitat. Free-floating, Indian Ocean and North Atlantic; and (dead) in North Atlantic muds. Always most abundant where the *Globigerinæ* are in greatest profusion, and the deposit of the purest kind.

2. *Coccosphæra Carterii* (Wall.).

Cell oblong. Long diameter about twice that of short diameter. Cell as in *C. pelagica*. *Coccoliths* varying in number from 16 to 38, more or less oblong, with two central apertures arranged lengthwise, margin finely and radially striate. Internal disk plain. Length of *Coccosphere* from $\frac{1}{1000}$ to $\frac{1}{800}$ of an inch. Length of coccolith from $\frac{1}{5000}$ to $\frac{1}{1000}$ of an inch.

Habitat. Free-floating, Indian Ocean, and Mid-Atlantic. (N.B. I have not observed any intermediate form between the spherical and oblong.)

It only remains for me to add, that I have not referred in the course of the preceeding observations to the highly important researches of Sorby, Oscar Schmidt, Haeckel, Gümbel, and others, simply because my own inquiries have been directed principally towards an aspect of the subject upon which they have hardly touched at all—my object having been to sustain the accuracy of my own observations, not to question that of others.

Note on Gromia. I hasten to correct an oversight on my part, which I have at all events the satisfaction of knowing has been shared by Dr. Carpenter and other writers.

Since the publication of my paper "On *Gromia* as the type of Foraminiferal Structure" ('Annals' Feb. 1877), I have

seen it incidentally stated that "nuclei" had been observed in *Gromia* by Max Schultze. On turning to Dr. Carpenter's 'Introd. Study Foram.' pl. iv. fig. 13, I found, as I expected, the figure of a highly magnified view of a mass of sarcode, containing two spherical granular masses, the explanatory description being as follows:—"Nuclear bodies? [*sic*] imbedded in the sarcode of *Gromia*. After Schultze." Not having Schultze's work to refer to, it is out of my power to say whether these bodies represent true *nuclei* or merely *sarcoblasts*. But be this as it may, if the credit of the discovery of a nucleus in *Gromia* be due to Schultze, most cheerfully do I cede it to that distinguished observer.

EXPLANATION OF PLATE XVII.

Fig. 1. *Coccosphæra pelagica* (Wall.), with its complement of *coccoliths*.
Fig. 2. Cell-wall of same, showing distinct membranous outline; most of the *coccoliths* having been thrown off.
Fig. 3. *Coccosphæra Carterii* (Wall.).
Fig. 4. The same in the *dehiscent* (?) condition.
Fig. 5. *Coccolith* of *C. pelagica* seen from external aspect; showing the radiate striation on margin of outer disk, and the central depression which constitutes the "central clear space" of Huxley.
Fig. 6. *Coccolith* of *C. Carterii*; side view, showing the *two* central depressions and radiate marginal striæ, together with the inner disk and intermediate piece.
Fig. 7. The same, as seen from its external aspect, this being, in short, a front view of the outer disk. Here also the two button-hole-like depressions are shown.
Fig. 8. Circular *coccolith* of *C. pelagica* occasionally met with.
Fig. 8 *a*. A specimen of a form of *coccolith* occasionally but rarely occurring, in which there is no central depression, but apparently an aperture close to the margin of the outer disk.
Fig. 9 D. Diagrammatic, enlarged, side view of coccolith of *C. pelagica*.
Fig. 10 D. Diagrammatic vertical section of same, showing the central depression (*a*), in external disk: *s*, the stem; *e d*, the inner disk.
Fig. 11 D. Diagrammatic front view of the outer disk of same: *a*, the central depression, the "central clear space" of Huxley, and "nucleus" of other writers; *b*, the innermost ring, indicating the margin of this depression; *c*, the ring indicating the outline of the intermediate piece, or stem uniting the two disks; *d*, the ring indicating the margin of the inner disk; *e*, the outline of the outer disk itself. *Possibly* these are the rings referred to in Prof. Huxley's Report of 1868, when describing the *coccoliths* as "curious rounded bodies, to all appearance consisting of several concentric layers surrounding a minute clear centre."
Fig. 12 S. This figure is copied from fig. 20, plate 16, appended to Prof. Oscar Schmidt's paper "On Coccoliths and Rhabdoliths" Annals & Mag. Nat. Hist. Nov. 1872, translated by W. S. Dallas, F.L.S. It is described in the text (p. 367) as "a decided coccolith with a dorsal shield, as may be ascertained by placing it on its edge, the dark non-granular part, *b*, representing the granular zone, and the clear spaces in it; *a*, *divided medullar space without central granules*."

Figs. 13 H, 14 H, and 15 H. Three figures copied from the plate accompanying Professor Huxley's paper; described as "Cyatholiths from the Atlantic Mud." The central corpuscle with its clear space, *a*, in the centre is shown in figs. 13 and 14. The "granular zone," *g z*, is shown in fig. 15.

Fig. 16 represents a two-celled or chambered *coccosphere*—being apparently the first stage in the formation of the *coccolith*-covered *Textulariæ* and *Rotaliæ* which have been described by me in former papers, and of which mounted specimens are extant.

Fig. 17. A *coccolith* of *C. Carterii* as seen in preserved specimens, an aggregation of granules being observable around the stem between the outer and inner disks, the so-called "granular zone" of authors.

Fig. 18. Sporangium of a protophyte from Bengal, probably allied to *Ankistrodesmus*: *a*. the globular colourless and transparent sporangial cell; *b b b*, the kidney-shaped fronds of same. These never have a *flagellum* or cilia, and are not zoospores.

N.B. In figs. 5, 7, and 11 D the letters indicate the same portions of the structure.

MISCELLANEOUS.

On Anguillula intestinalis, *a new Nematoid Worm, found by Dr. Normand in subjects attacked by Diarrhœa of Cochin China.* By M. Bavay.

In the *post mortem*-examination of a man who died of diarrhœa of Cochin China, Dr. Normand found a very small worm, which he sent to me as distinct from my *Anguillula stercoralis**, which, however, was associated with it in the intestine. Having subsequently met with it in four other cases, I have ascertained that it is really distinct; and I think it useful to give a description of it.

I have been unable in this Nematoid to distinguish the arrangement of the muscular bands; and although I have examined more than two hundred individuals, I have never seen any spicula; hence it is impossible at present to fix its position in the modern classifications, such as that of Schneider. I shall therefore give it provisionally the generic name of *Anguillula* (*sensu latiori*), and distinguish it by the specific name *intestinalis*.

Length of the adult	2·200 millim.
Average breadth	0·034 „

Thus *Anguillula intestinalis*, with a less average breadth than that

* See Ann. & Mag. Nat. Hist. ser. 4, vol. xviii. p. 507.